

1 INTRODUCTION

In order to assess and to strengthen the basis for methods of solar diagnostics and to provide the relevant atomic data, we measured dielectronic recombination (DR) rate coefficients, electron impact excitation (EIE) cross sections, and radiative transition probabilities (A -values) for ions of importance in interpreting UV solar observations. Although theoretical methods for predicting A -values, EIE, and DR cross sections have become extremely sophisticated, there are very few direct experimental tests of the calculated values and their accuracy.

Dielectronic recombination is the dominant recombination mechanism for non-hydrogen ions in most low density, high temperature plasmas such as the solar corona. DR rates can be quite sensitive to the presence of external electric and magnetic fields because the recombining electron is often captured in a Rydberg state which is influenced by external fields. Until recently, most DR rate data for solar physics have been calculated for the zero electric field case, which is not appropriate for the upper solar atmosphere.

Electric-dipole, spin-changing (intersystem) transitions in low- Z ions frequently have rates for radiative decay *i.e.* A -values, that are many orders of magnitude less than those of typical electric-dipole-allowed transitions. Moreover because the rates for collisional excitation and deexcitation of low Z -ions in the diffuse solar atmosphere are of the same order of magnitude as the radiative decay rates for intersystem and forbidden transitions, intensity ratios involving intersystem lines within the multiplet or with forbidden or allowed lines can be applied to determine electron density and temperature. The line ratios depend critically on the decay rates and thus the solar plasma diagnostics are no more accurate than the atomic data used therein.

2 RESULTS FROM GRANT NAGW-1687 (10/1/93 - 2/28/97)

The research with the Ion Beam Facility was directed to measuring absolute rate coefficients for DR and EIE in C IV, one of the primary ions used for probing the solar transition region. Our study of DR was particularly concerned with the effects of electric and magnetic fields on the recombination rates, since fields having magnitudes comparable to those found in the solar atmospheres can enhance the C IV DR rate by as much as a factor of ~ 7 . The analyses of these DR and EIE measurements in C IV, the subject of the Ph.D theses of Dr. A. R. Young & Dr. Daniel Savin, have resulted in several scientific papers:

- Measurements of C^{3+} Dielectronic Recombination in a Known External Field*, Young, A. R., Gardner, L. D., Kohl, J. L., Lafyatis, G. P., Savin, D. W., Bliman, S. & Chutjian, A. 1994, Phys. Rev. A **49**, 357;
Absolute Rate Coefficients for C^{3+} ($2s - 2p$) Electron Impact Excitation, Savin, D. W., Gardner, L. D., Reisenfeld, D. B., Young, A. R. & Kohl, J. L. 1995, Phys. Rev. A **51**, 2162;
In Situ Absolute Calibration of a Channel Electron Multiplier for Detectors of Positive Ions, Savin, D. W., Gardner, L. D., Reisenfeld, D. B., Young, A. R. & Kohl, J. L. 1995, Rev. Sci. Instrum. **67**, 1;

Absolute Measurements of Dielectronic Recombination for C^{3+} in a Known External Field, Savin, D. W., Gardner, L. D., Reisenfeld, D. B., Young, A.R. & Kohl, J. L. 1996, Phys. Rev. A **53**, 280.

During this grant period a new electron cyclotron resonance (ECR) ion source was installed on the Ion Beam Facility as part of the Ph.D thesis research of Harvard graduate astronomy student, Mr. Daniel Reisenfeld. ECR sources have the ability to run stably for long periods of time. In its present configuration it was arranged to produce singly- and doubly ionized systems *e.g.* Si^{2+} . Measurements of EIE of $3s^2-3s3p$ and $3s3p\ ^3P^0 - 3p^2\ ^3P$ with the radiation at 1200 Å and 1300 Å have begun. Preliminary cross sections at two energies have already been measured. More data collecting is underway to improve the statistics of the measurements.

The research with the Ion Trap Facility was directed at the measurement of *A*-values or spin-changing (intersystem) electric-dipole transitions in low-Z-ions. Intensity ratios involving intersystem lines within the multiplet, or with forbidden or allowed lines are the basis for the best diagnostics to determine electron density and temperature.

Harvard physics graduate student Mr. Adrian Daw has upgraded the Facility with computer controlled power supplies, computer interfaces and software. As part of his Ph.D thesis research, he is completing measurements of the radiative lifetime of the $2s^22p^4\ ^1S_0$ level in Ne III which decays by forbidden lines (magnetic dipole & electric quadrupole transitions) at 1815 and 3344 Å. Daw's measurement is the first radiative lifetime determination for an excited term in the ground configuration of a second period atomic ion and provided the first experimental test of calculations of forbidden line decay rates for these astrophysically abundant ions. In the course of this work on Ne^{2+} he discovered that the identification of the $Ne\ \lambda\ 32.3\text{ nm}$ intersystem doublet in the solar spectrum was in error.

For this past grant period we completed and published the following papers on the measurement of *A*-values and radiative lifetimes:

Measurements of the Transition Probability of the C III, 190.9 nm Intersystem Line, Kwong, Victor H. S., Fang, Z., Gibbons, T. T., Parkinson, W. H. & Smith, P. L. 1993, ApJ **411**, 431;
Measurements of Radiative Decay Rates of the $2s^22p\ ^2P^0 - 2s2p^2\ ^4P$ Intersystem Transitions of C II, Fang, Z., Kwong, Victor H. S., Wang, J. & Parkinson, W. H. 1993, Phys. Rev. A **48**, 1114;
Radiative Lifetimes of the $2s2p^2\ ^4P$ Metastable Levels of N III, Fang, Z., Kwong, Victor H. S. & Parkinson, W. H. 1993, ApJ Lett. **413**, L141;
Transition Probabilities for the $3s^23p\ ^2P^0\ 3s3p^2\ ^4P$ Intersystem Lines of Si II, Calamai, Anthony G., Smith, Peter L. & Bergeson, S. D. 1993, ApJ **415**, L59; and
Transition Probabilities for the $3s^23p^2\ ^3P_{2,1}\ 3s3p^3\ ^5S_2^0$ Intersystem Lines of S III, Heise, Claas, Smith, Peter L. & Calamai, Anthony G 1995, ApJ Lett. **451**, L41;
Radiative Lifetime of the $2s^22p^4\ ^4S_0$ Metastable Level of Ne^{2+} , Daw, A., Calamai, A. G., Parkinson, W. H. & Smith, P. L. 1996, DAMOP, Ann Arbor, Michigan.